

Spectral Properties of Short Gamma-Ray Bursts

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Abstract. The distribution of GRB durations is bimodal, but there is little additional evidence to support the division of GRBs into short and long classes. Based on simple hardness ratios, several studies have shown a tendency for longer GRBs to have softer energy spectra. Using a database of standard model fits to BATSE GRBs, we compare the distributions of spectral parameters for short and long bursts. Our preliminary results show that the average spectral break energy differs discontinuously between short and long burst classes, but within each class shows only a weak dependence on burst duration.

Various studies have shown that short and long GRBs are statistically different classes [4,7,1,9,6]. Recently, additional evidence has come from a study by Norris et al [11], who found no measurable energy-dependent pulse lag in the time histories of short events. This is in contrast to long GRBs, which clearly show such a lag [10], even for short subpulses. Moreover, in bursts with measured redshifts (which thus far are all long events), the energy-dependent pulse lag appears to be anti-correlated with burst luminosity [10]. Thus, if the mechanism producing the lag works for short bursts, they must be intrinsically more luminous than long bursts, and therefore more distant. Alternatively, a different mechanism may operate in short events. Either way, the evidence seems to support separate classification of short and long GRBs.

In the currently favored fireball model, the prompt burst emission is thought to be optically thin synchrotron or synchrotron self-Compton emission from internal shocks, as external shocks are unable to produce the observed temporal structure [5,16]. Detailed studies of the spectra of a number of bright GRBs, including both long and short events, have shown good consistency with the synchrotron shock model [17,18,2]. However, more comprehensive analyses have uncovered problems with this interpretation [3,13,15]. In particular, some GRB spectra are harder at low energies than the synchrotron limit [3,13]. These conclusions are based mostly on spectroscopy of long bursts, but the problem may be most acute for short bursts because their spectra are on average harder.

Recent work [12,14] has characterized the range of spectral behavior in bright, long bursts in some detail, but the spectral properties of the class of short bursts have only been characterized using hardness ratios. Phebus data showed that short GRBs are harder than long ones [4] (confirmed by many succeeding analyses of BATSE data), but detailed study of the spectral differences between short and long bursts has not been done. In particular, the consistency of short burst spectra with the synchrotron shock model predictions has not been properly

tested. It is clear that a better characterization of the spectral differences between short and long bursts is warranted. For the foreseeable future, the BATSE data base will provide the best sample of bursts for this purpose.

The BATSE *CONT* datatype is derived from the large area detectors and is independent of the BATSE trigger. However, the *CONT* data have 16-channel energy resolution and 2 s time resolution, so they are not optimal for the analysis of the spectra of short events because the 2 s integration degrades the signal-to-noise ratio. Nevertheless, a database of *CONT* fits was conveniently available [8], so we used these data to perform a preliminary study of spectral differences between short and long GRBs. The *CONT* fit database contains spectral fits for ~ 1200 BATSE GRBs. Fit results for two spectra per burst (peak flux interval and total fluence interval) are available, generally from four different spectral models. For a given event, fit results may not be available for all models due to poor statistics and/or lack of fit convergence.

We extracted spectral parameters for all GRBs in the *CONT* database for three of the models (cut-off power law, broken power laws, and the Band GRB function). For short events, there is little difference between the peak flux and fluence intervals because of the 2 s *CONT* time resolution, whereas long GRBs typically have harder spectra at the time of peak flux. We binned the results for each spectral fit parameter according to the burst duration. Since the distribution of spectral parameters within each duration bin is broad and approximately Gaussian, we computed the centroid and width of the best-fitting Gaussian for each duration bin. Figure 1 shows an example of the parameters for the cut-off power law model fit to the peak flux intervals, plotted as a function of burst duration. The left panel shows the power law spectral index and the right panel shows the cut-off energy. Within a given duration interval, the thin vertical bars show the width of a Gaussian fit to the parameter distribution, and the thick vertical bars show the error in the mean of the distribution. Although the distributions are broad, there appear to be differences in the trend of the parameters with GRB duration. The hardening trend in the power law index is roughly continuous throughout, whereas the trend in the cut-off energy appears more like a step-function, with a discontinuity around a duration of 2 s, consistent with the minimum in the T_{90} duration distribution.

Although no quantitative analysis of the statistical significance of these results has yet been done, distributions of fit parameters for the other models show essentially the same trends for both peak-flux and fluence intervals. (The broken power law and Band GRB function fits provide a third parameter, the high energy power law index, but the statistics of this parameter are not yet good enough to define clearly its trend with duration.)

It would appear from the right panel of Figure 1 that the energy spectra of short and long GRBs have different characteristic break energies that otherwise depend only weakly on duration. Since the break energy is affected by the Lorentz factor of the expanding fireball as well as by the redshift of the emitting source, this places interesting limits on the nature of the sources. Either the short GRBs have higher bulk Lorentz factors or they are located closer to us than long GRBs,

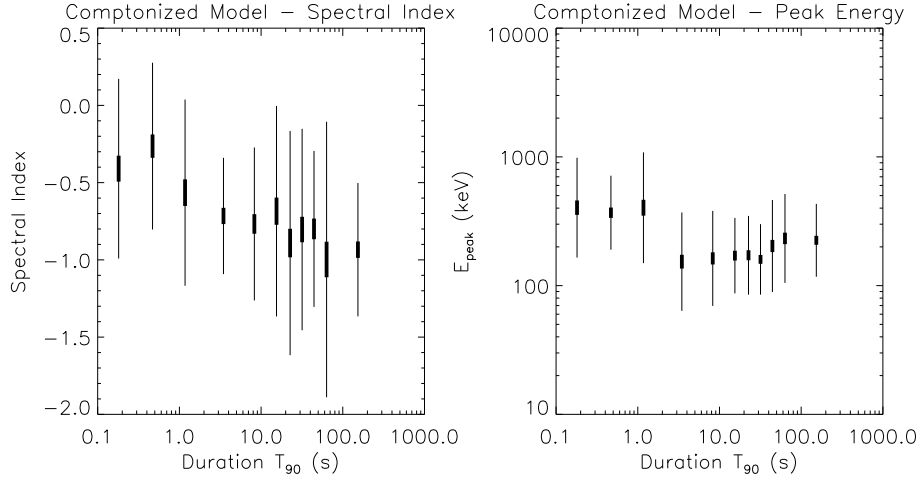


Fig. 1. Spectral parameters as a function of burst duration for fits of a Comptonized model (power law with exponential high-energy cut-off) using *CONT* data (see text). Thin vertical bars show the width of a Gaussian fit to the parameter distribution within a duration bin and thick vertical bars show the error in the mean of each distribution.

or both. Discovering optical counterparts for short GRBs and measuring their redshifts would clearly help resolve the nature of these sources.

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